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1 **Consumer acceptability of plant-based, seaweed-based and insect-based**
2 **foods as alternatives to meat: A critical compilation of a decade of research**

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26 **Abstract**

27 There is a growing criticism of meat-based products over environment, animal welfare, and
28 public health. Meat lovers are keeping and adapting their habits, while other consumers are
29 increasingly shifting towards meat alternatives considered as healthier and more sustainable
30 options to replace the animal-based products. This transition gives room in the market to plant-
31 based, seaweed-based, and insect-based food products. Nevertheless, these emerging markets
32 are still facing the challenge of consumers' acceptance and the uncertainty in terms of
33 preferences. This paper focuses on in-depth understanding of consumer perception and
34 acceptability of plant-, seaweed-, and insect-based foods to get insights on their current situation
35 and future implementation. The main factors and motives influencing the consumer perceptions
36 towards meat alternative products are reported. Further, the consumers' motives and drivers to
37 consume alternative products were highlighted. This review, provides a better understanding of
38 motives and drivers of consumers' acceptance to improve the acceptability of meat alternatives,
39 considering product and country origin of the consumers of meat alternative foods.

40 **Keywords:** Meat alternatives, Novel foods, Consumer acceptance, Habits and Preferences, Food
41 innovation.

42 1. Introduction

43 Meat is an important source of nutrients, *e.g.*, proteins, iron, and vitamins, with beneficial
44 effects on human health (Gagaoua & Picard, 2020). Meat consumption has been increased since
45 the era 60s, but particularly from the era 80s decade to nowadays (González et al., 2020), which
46 can be attributed to increased population and income. As such, the meat industry is facing a
47 challenge to meet the growing consumer extractives for meat products. With a growing world
48 population expected to reach about 9 billion by 2050 (United Nations, 2019), the demand for
49 meat and meat products is projected to double by 2050. The situation is alarming for a certain
50 category of population as more meat production means for them more gas emission and carbon
51 footprint, especially for red meat. For example, livestock production results in greenhouse gas
52 emissions, about 14.5% (Gerber et al., 2013) and uses considerable amounts of freshwater
53 (Gerbens-Leenes et al., 2013). Several studies reported that excessive consumption of red and
54 processed meat products can be related to adverse health effects (Bouvard et al., 2015; Godfray
55 et al., 2018). Furthermore, farm animal suffering is a major ethical concern in many developed
56 countries since appeals for animal welfare has got less attention as compared to the human health
57 (Mathur et al., 2020). For instance, the animal welfare in Sweden is still a debate, where animals
58 are not considered as sentient creatures but as production factors and commodities for economic
59 benefit. Food production systems were reported to be harmful to animals at different degree
60 depending the type of harm caused. 4 types pf harms were identified: i) keeping of animals in
61 captivity; ii) causing deliberate harm to animals through slaughter, fishing, or hunting; iii)
62 causing direct but unintended harm to animals such as vehicle collisions; and iv) negatively
63 affecting the welfare of animals indirectly by disturbing ecological systems. This contributed
64 into the criticism of meat products from environmental, animal welfare, and public health
65 perspectives.

66 Replacing animal meat with sustainable alternative proteins such as plant-based meat
67 products was suggested as a promising approach to satisfy the consumers' needs and in certain
68 cases to reduce meat consumption. In recent years, substantial investment in plant-based and lab-
69 grown meat has been pumped from private and public sectors. As a result, alternative plant-based
70 meats hold an important share of the global market and made available in popular franchises like
71 McDonald' and Burger King. The global meat alternative market size was valued at \$4,512.1
72 million in 2019, and is projected to reach \$8,823.6 million by 2027, exhibiting a compound
73 annual growth rate of 7.2% from 2021 to 2027 (Nitesh Chouhan et al., 2021). Growing niches,
74 *i.e.*, vegetarians, vegans and flexitarians, are a key segment driving the boom as their gateway

75 for a more sustainable and healthier meat substitute (Boukid, 2021). Furthermore, changes in
76 food habit during the COVID-19 outbreak boosted the raise of alternatives products as
77 consumers were seeking healthier and more functional foods (Ayivi et al., 2021; Profeta et al.,
78 2021a). The changes in food habit during the COVID-19 outbreak were driven by two main
79 factors staying at home (imparting changes in amount, quantity and quality of food) and
80 stockpiling food (impacted by food availability in groceries). In addition, social media reporting
81 continuously about the COVID-19 might another cause of stress leading consumers to be careful
82 about their meals. It was reported that people decreased the junk food (snacks and products rich
83 simple sugars) consumption during the quarantine as foods associated with increased risks of
84 cardiovascular diseases. For the same reasons, proteins from non-animal sources gained traction
85 as an alternative to meat products due to their low fat and saturated fatty acids and thus lower
86 cholesterol. For instance, COVID-19 outbreak boosted the raise in veggie burgers and a drop in
87 meat burgers launches during 2019 in Europe. In the USA, the sales plant-based meat alternatives
88 increased by almost 200% in 2020 compared to 2018.

89 Sensory attributes of meat products such as flavour, texture, and appearance are important
90 factors for the acceptance and eating behaviour (Brückner-Gühmann et al., 2019; Hartvig et al.,
91 2014). The partial or total replacement of meat by plant-based, seaweed-based, and insect-based
92 foods could be a healthier or/ and more sustainable alternative (Gullón et al., 2020a; Lee Hyun
93 Jung Yong Hae In, 2020; Sadler, 2004); however, consumers remains often hesitant towards new
94 or unfamiliar foods (Tan et al., 2016). Therefore, consumers' preferences for alternative and
95 novel meat products are still unknown and uncertain due to the multifactorial decision. For
96 example, several factors might impact the acceptance of consumers including sex, gender,
97 income, geography and cultural habits, and product type. Therefore, this review aimed to gather
98 the current knowledge about consumer perception and acceptability of meat alternatives (*i.e.*,
99 plant-, seaweed-, and insect-based foods) and enable recommendations for future
100 implementation and action in this sector. To do so, the literature was searched in Pubmed, Scopus
101 and Google Scholar databases to gather all the papers published in the field of plant-, seaweed-,
102 and insect-based products for human food consumption since 2010 upon June 2021. We used
103 the keywords “perception*consumers*plant-based*food, perception*consumers* Insect-
104 based*food, perception*consumers*seaweed* based products, perspective* consumers*plant-
105 based*food, perspective*consumers*insect-based*food, and perspective* consumers*
106 seaweed*based*food” to identify the related articles.

107 A total of 11 150 articles were retrieved in the first step with 7367, 247 and 2541 articles
108 identified for plant-, seaweed-, and insect-based products, respectively. The articles that do not
109 belong to agricultural and biological sciences, environmental sciences, economic and business,
110 social sciences, and chemistry were excluded. A total of 7264 articles (6308, 148, and 808
111 articles, respectively) were retained in the second step. The review was limited to peer-reviewed
112 research articles published in English during the last decade (2010 to 2021) and focusing on
113 consumer preferences, perceptions, acceptance and behavior. A total of 519 articles (431, 13,
114 and 75 articles) were selected. From these, 442 papers were excluded because the studies were
115 not strictly related to consumer research for products as meat substitutes. Finally, 85 research
116 articles were retained as eligible (see **Table S1** and **Figure S1** for the full list of the papers and
117 the flowchart highlighting the selection process of the articles, respectively).

118 The selection process meant to select peer-reviewed articles related to the topic of this
119 review. The selected articles have the country where the review was conducted and the plant-,
120 seaweed- and insect-based products investigated. The criteria of selection of the articles were
121 briefly summarized in **Table S2**. In terms of methodologies, in brief, the data in the 85 eligible
122 research articles were collected by quantitative approaches using interviews, questionnaires,
123 online surveys, or choice experiments (sensory testing) and conjoint analysis. Qualitative
124 approaches such as focus groups were in certain of the studies used to investigate if the trends of
125 consumptions by consumers are linked to the perceptions of the new proposed products. The
126 factors influencing the preference, perception, and acceptance of the consumers related to the
127 products and the motives behind consumption were identified and commented accordingly
128 (**Tables 1, 2 and 3**). In this review, consumer perception of alternative products (plant-based,
129 seaweed-based, and insect-based) were discussed to understand the consumer behavior and the
130 motives influencing the perception and acceptability. Furthermore, this review explored the
131 factors influencing the acceptability of these products considering country as variable.

132 **2. General findings**

133 General findings are described first regarding the studies with a focus on the main factors
134 and motives influencing the consumer perceptions, the meat alternative products (plant-,
135 seaweed-, and insect-based foods) and countries related to the impact on the acceptability.
136 Therefore, this review reviewed the main factors driving consumer acceptance of plant-,
137 seaweed-, and insect-based products – for example, food choice motives (Onwezen et al., 2021;
138 Vainio, 2019), consumer attitudes towards alternative proteins (Lemken et al., 2017), and

139 familiarity with meat alternatives (Palmieri & Forleo, 2020; Schlup & Brunner, 2018; Verbeke,
140 2015).

141 This review revealed that the consumer studies related to meat alternatives increases
142 rapidly as most of them were published in the last five years (during 2016-2021). For the plant-
143 based products, the studies are mostly conducted during 2016-2017, while the insect food
144 products are very recent and conducted during the last two years (2020-2021). These indicate
145 that the studies related to plant-based products are currently booming as meat product
146 alternatives. There were 40 studies related to the insect food products found in the literature
147 search with variety of products, but the insect sources are mostly obtained from cricket and
148 mealworm. Only few studies related to seaweed products are found. However, seaweeds as
149 natural sources containing higher proteins have a great potential to be used as meat alternatives,
150 for the design of functional meat products based on seaweeds and their extracts or to reformulate
151 new meat products enhancing their healthy attributes (Gullón et al., 2020a).

152 Several of the consumers' acceptance studies have focused on specific cases of alternative
153 proteins such as insects (Adámek et al., 2018; Balzan et al., 2016; Bartkiewicz et al., 2017;
154 Caparros Megido et al., 2014), plant-based meat alternatives (Michel et al., 2021; Vainio, 2019;
155 van Loo et al., 2020; Wang & Scrimgeour, 2021a), edible seaweed (Palmieri & Forleo, 2020),
156 burgers (Schouteten et al., 2016; Slade, 2018), etc. Considering the country as discriminative
157 factor, European countries dominated research studies on meat alternatives from plant- or insect-
158 based products. Specifically, Germany (Hartmann et al., 2015), Denmark (Verneau et al., 2016),
159 and The Netherlands (Lensvelt & Steenbekkers, 2014) focused on plant-based products, while
160 The Netherlands (House, 2016; Marberg et al., 2017; Pascucci & de magistris, 2013), Belgium
161 (Bryant & Sanctorum, 2021) and Italy (Cicatiello et al., 2016; Verneau et al., 2016) were
162 interested on investigating the insect-food products. The U.S.A., China (Hartmann et al., 2015;
163 Wang & Scrimgeour, 2021a), New Zealand (Wang & Scrimgeour, 2021b) and Australia (Lensvelt
164 & Steenbekkers, 2014) have also focused on this topic. On another hand and as stated above,
165 these studies were conducted *via* structured surveys and questionnaires, which are common
166 methods to understand the consumer perceptions. These methods are proved to be effective to
167 gain high numbers of participants enabling high accuracy of the results regarding the response
168 of participants to these meat alternatives. Indeed, more than a thousand participants were
169 involved in about 25% of the retrieved studies.

170 3. Motives influencing the consumers' perception on new meat alternatives

171 Motivations behind consumer acceptance can be related to conventional drivers (sensory,
172 taste, cost, and convenience) or/and emerging drivers (health and wellness, safety, environment,
173 animal welfare and familiarity) (Boukid, 2021; de Boer et al., 2013; Schösler et al., 2012; Siegrist
174 & Hartmann, 2019). Based on the retrieved studies (**Tables 1, 2 and 3**), the main product-related
175 drivers are healthiness, taste (de Boer et al., 2013), convenience, environmental benefits (de Boer
176 et al., 2013; Vainio, 2019), and appearance (Bryant & Sanctorem, 2021). These factors are of
177 high relevance to make purchase decisions.

178 The motives over environmental concerns are the most influential factors for the
179 consumers to change their eating behavior and shift toward consuming more meat alternatives
180 as a more sustainable manner to those based on solely meat (de Boer et al., 2013; Schösler et al.,
181 2012; Siegrist & Hartmann, 2019). Even though environmental impact is underestimated (or
182 misunderstood) in few countries, like Switzerland (Hartmann & Siegrist, 2017; Lazzarini et al.,
183 2017), tailored marketing strategies promoting plant-based foods and insect foods as sustainable
184 options to conventional meat increased the willingness to buy or to consume type of products in
185 different countries (Circus & Robison, 2019; Imm et al., 2021). These category of consumers can
186 be considered as “environmentally conscious”(Hoek, 2010; Schösler et al., 2012). The pro-
187 environmental behavior is truly personal because of the underlying moral attitudes and values.
188 The motivation for dietary change depends then on the involvement of consumers with “green”
189 background *e.g.*, reducing environmental impact (de Boer et al., 2013) and sustainability (Hoek
190 et al., 2017). Indeed, sustainability and environmental benefits of seaweed have been mentioned
191 by in few papers to have a positive influence on the consumption of seaweed-based products
192 (**Table 2**).

193 Regarding health and nutrition benefits, (Verbeke, 2015) argue that when there is a relation
194 between functional ingredients and the health benefits of the products in consumer insights, the
195 products would be perceived positively by consumers as further confirmed in other studies (de
196 Boer et al., 2013). Consumers’ awareness over the health benefits of the plant-based products
197 leads to the willingness to consume thereby to change their eating behavior (Biondi & Camanzi,
198 2020). Also, the seaweeds containing bioactive compounds are conferred to have health
199 properties (Gullón et al., 2020a) and can be used to reformulate new functional foods
200 (Nadeeshani et al., 2021) or meat products judged by some consumer as “bad” to improve certain
201 of their nutritional aspects (Gullón et al., 2020b). (Schouteten et al., 2016) reported increased
202 demand of insect burger due to targeted campaign on insect food benefits. The knowledge about

203 the content of the meat alternatives also contributes into the change of eating behavior of the
204 consumers. The font-of-pack labeling is the tool that can help consumers to make informed
205 choice while purchasing a food product. Nutritional labeling is also very important to enable a
206 further understanding of the healthiness of the alternative products compared to conventional
207 ones through the list of ingredients, nutritional facts, health claims, nutrient content claims and
208 allergens.

209 The concern to animal welfare was found to be psychologically increased for many people.
210 For example, (Wang & Scrimgeour, 2021a) reported that animal welfare is the motives for people
211 in New Zealand to consume plant-based products because of their low affinity to animal-based
212 foods. In another report, (Graça et al., 2015) reported the willingness to change eating behavior
213 to plant-based foods to minimize animal suffering.

214 Besides the above-mentioned factors, price, taste and appearance are also relevant factors
215 that can influence consumer willingness to buy alternative meat products (Boukid, 2021; de Boer
216 et al., 2013). The challenges that meat alternatives still facing are the low ignorance about their
217 composition, molecular interactions, nutritional benefits, and sensory attraction including off-
218 flavor (Bahmid et al., 2020; Brückner-Gühmann et al., 2019; de Boer et al., 2013; Haard, n.d.;
219 Hoek, 2010; Pagliarini et al., 2021; Schouteten et al., 2016). Many non-consumers of meat
220 alternatives agree that the meat alternatives would be more attractive if their price is lowered and
221 their nutritional composition is improved compared to meat and meat products. Indeed, current
222 meat alternatives have lower protein and higher fat, carbohydrates and sugar contents compared
223 to their meat-based counterparts (Boukid & Castellari, 2021). Appearance is of great importance
224 but innovative technologies for alternative proteins texturization are rapidly growing aiming to
225 improve this aspect and reach a meat-like experience and properties (Ismail et al., 2020). In this
226 perspective, several challenges and limitations must be overcome to improve the flavor profiles,
227 for instance, of plant-based proteins (Karolin Mittermeier-Kleßinger et al., 2021).

228 According to (Renner et al., 2012a), the environmental aspect is only perceived by the
229 consumers as additional benefits and is not the only driving factor for deciding about the food
230 alternatives. Hedonic factors, like price, appearance and taste are still the most important factors
231 (Siegrist & Hartmann, 2019). For the seaweed products, sensory and composition characteristics,
232 like taste and ingredients, are important drivers (Palmieri & Forleo, 2020). For example,
233 (Lazzarini et al., 2017) suggested that it is important to improve the texture, taste, appearance
234 and price of the meat substitutes when sensory is the dominant driver (van Loo et al., 2020),

235 whereas health claims are more persuasive when health benefits are the main consideration
236 (Biondi & Camanzi, 2020).

237 Some studies reported cultural and social issues *e.g.*, value, emotion, experience,
238 knowledge, and feeling also influence the consumers for decision to consume plant-based
239 products. (Hoek, 2010) found that the main reason for plant products preference is familiarity
240 and experience. Certain consumers accept bean-based products as meat alternatives, like insect
241 burgers with high protein content because of the previous experience to consume such products
242 (Aschemann-Witzel & Peschel, 2019a; Schouteten et al., 2016). Neophobia is an issue for many
243 consumers having fear of eating unfamiliar products such as those made with insects and
244 seaweed (Caparros Megido et al., 2016; Hartmann et al., 2015; Verbeke, 2015). (Hoek et al.,
245 2011) found also compared to muscle foods, the meat substitutes are more ethical, but due to the
246 absence of a strong ethical orientation, meats are selected over meat alternatives. In addition, the
247 situation where meat substitutes are consumed and under which social norms may also have an
248 influence on perceived feasibility. In this context, a study of attitudes has shown that people tend
249 to adjust their eating behavior according to their colleagues' eating behavior (Higgs & Thomas,
250 2016). As an example, hosts serving vegetarian foods to their colleagues have more awareness,
251 alternative, health awareness, and concern to animal welfare than hosts serving meat foods
252 (Funk, Sütterlin, & Siegrist, 2020). Therefore, the eating situation could also influence the
253 acceptance of meat substitutes.

254 Versatility of the products as meat alternatives to fulfil the consumer needs could be an
255 advantage as well. For example, in Belgium, the consumers have the pleasure to consume
256 different products from myriad sources such as legumes, pulses, cereals, insects, and seaweeds
257 (Bryant & Sanctorum, 2021). Such a rich product portfolio is considered as the market
258 establishment for the meat alternatives. Even though, these factors can have an influence on the
259 consumer preference, other factors like taste and healthiness still have a more pronounced impact
260 on the overall consumer perceptions (Hoek et al., 2017). In relation to the social issues, the
261 quality of the food alternatives should be guaranteed to maintain the market, because the bad
262 experience in the first consumption of the meat alternatives leads to an ignorance to the
263 forthcoming consumptions (Hartmann & Siegrist, 2016, 2017). Product standardization and
264 quality stability and tractability are deemed keys factors for investors to maintain or to expand
265 the alternative products market.

266 **4. Product related consumers' acceptability**

267 4.1. Plant-based meat (nugget, burger, etc)

268 Steak patterns differ significantly from alternative meat products and processed meat
269 products (Michel et al., 2021). The processed meat products, e.g., chicken and vegetarian nuggets
270 or beef and vegetarian burgers have similarities in terms of form, processing steps and
271 ingredients such as starches, soy proteins, emulsifiers and hydrocolloids (Boukid & Castellari,
272 2021). Nevertheless, there is no logical evidence or sense to compare a meat substitute to a steak.
273 Nevertheless, it is important to mention that both research and market for the replacement of
274 processed meat products e.g., chicken nuggets or beef burgers with plant-based substitutes are
275 increasing and promising, respectively (Faber et al., 2020). In terms of consumers acceptability,
276 Belgian and Dutch respondents, for example, perceived the term “plant-based diets” more
277 attractive than vegetarian (Faber et al., 2020). (van Loo et al., 2020) investigated the consumer
278 preference in USA and identified that 16% of people prefer consuming plant-based burgers,
279 compared to the growing-lab meat with only 7%. The percentage of preference of the consumers
280 is to some extent and was established to be around 21% (Slade, 2018). In the United Kingdom,
281 90.6% of surveyed participants would consume plant-based substitutes (Circus & Robison, 2019).
282 The information related to insect food benefits, is however, increasing the demands to insect
283 burgers (Schouteten et al., 2016). Overall, the motives of consuming alternative burgers are
284 mainly related to the environmental impact, health and animal welfare, but consumers are
285 perceiving that plant-based meats should have a similar appearance to that of meat-burger.
286 (Peschel et al., 2019) also reported that the mention “minimally processed” food has benefits in
287 terms of sustainability and environment.

288 4.2. Oil seeds and legume products

289 Tofu and Tempe for example have been known for long time, but meat lovers are not
290 interested on the soybean products because of the taste, flavor (mainly off-flavor as mentioned
291 above) and other sensory attributes (Hoek et al., 2017). The vegetables (or legumes) are of
292 interest because of the health, and environmental benefits and innovation in this sector is opening
293 plenty of opportunities to emerging sources such as peas, chickpeas, and lentils especially after
294 Food and Agriculture Organization of the United Nations declaring 2015 as the year of pulses
295 (beans, lentils, and peas) (Lemken et al., 2017). On the other hand, soybeans have used
296 historically as food ingredients. Nevertheless, they have a poor reputation since soybeans are one
297 of the most widely used genetically modified organisms (Aschemann-Witzel & Peschel, 2019a).
298 Generally, participants in certain surveys addressing this specific point agreed that they would

299 avoid soy protein, as soy has been documented as a health risk (e.g., ‘soy is allergic’)
300 (Aschemann-Witzel & Peschel, 2019a). Given this critical stance, it may not be advisable for
301 food manufacturers to invest in extracting proteins from plants that are considered unhealthy.

302 *4.3. Snack from seaweed and edible seaweed*

303 The edible seaweeds have an interesting possibility to be a meat alternative, because of the
304 nutrients and healthy compounds with myriad functionalities (Gullón et al., 2020b; Milinovic et
305 al., 2021). For example, (Palmieri & Forleo, 2020) found that 76% of participants have a
306 willingness to eat seaweed. Around 12% over a thousand participants prefer consuming snack
307 from seaweeds, which was higher than insect-based snacks (de Boer et al., 2013). The seaweed
308 consumers mostly are young males (Milinovic et al., 2021). In addition, most of seaweeds
309 consumers are those who tend to eat fish (de Boer et al., 2013). Similarity of flavors between
310 seaweeds and fish gives a feeling a familiarity to consumers, which might reduces neophobia.
311 Accordingly, familiarity has an influence since 57% respondents had an experience eating the
312 seaweed in the past (Losada-Lopez et al., 2021).

313 *4.4. Edible insects*

314 Strong disgust responses and aversion are still relevant obstacles for the consumers’
315 acceptance to edible insects (Circus & Robison, 2019; la Barbera et al., 2018, 2021). Edible insect
316 as a food ingredient is still not really understood, but insect foods could be a future dish on
317 European tables as new source of proteins (Mancini et al., 2019; Moruzzo et al., 2021). Some
318 studies proposed for example to use insect proteins as additives or supplements in bread, but the
319 findings of the survey conducted by the authors revealed that most participants were unwilling
320 to try such bread (Ribeiro et al., 2021). Thus, sensory properties need to be evaluated to increase
321 the willingness of consumers to purchase new insect-based food products. The promotion of the
322 healthiness of the edibles insects needs to target all consumers (Imm et al., 2021; Possidónio et
323 al., 2021). (Schouteten et al., 2016) reported that Western consumers have more willingness to
324 consume insect burgers. Another product, like mealworms and house crickets, associated with
325 known flavors and crispy textures were appreciated better (Caparros Megido et al., 2014).
326 Although differences might exist between genders, the nutritional information, benefits and
327 sensory quality affect emotion and willingness of the consumers, so it is important to improve
328 the sensory quality and provide information related health benefits consuming the insect

329 products. Therefore, informative nutritional labeling can play key role in the purchase decisions
330 especially for label readers.

331 **5. Country related consumers' acceptability**

332 Country has an influence on the perception and motives of consumers for each country
333 since differences exist in the cultures, habits and behaviors (Lazzarini et al., 2017).

334 In Western Europe, the positive response to plant-based products for Mediterranean
335 countries is related to the long-term importance of these staple foods in their diets (González et
336 al., 2020). Dutch and Belgian people have initially negative responses to plant-based food
337 products, knowledge related to the benefits of the products increases the acceptance of the
338 products (Faber et al., 2020). The acceptance of the insect-based products in the Netherlands is
339 some extent high, which 45% of participants have an interest to try the insect foods (Mancini et
340 al., 2019). In Belgium, people have still negative response to meat alternatives. However, there
341 is a possibility to market new meat alternatives. Around 43% females and young consumers in
342 Northern Flanders respond positively to plant-based products. The information related to the
343 benefits of the insect food increases the interest of Belgian to consume such food (Schouteten et
344 al., 2016). The satisfaction of Belgian as an example to toward meat alternatives increased from
345 44 % (2019) to 51% (2020) (Bryant & Sanctorum, 2021), which can be attributed to the quality
346 improvement of plant-based products and the increase of awareness towards animal welfare and
347 environmental issues during these years. Similar trend was also observed in France, where
348 nutritional information and environmental benefits are significantly driving consumer
349 willingness to purchase meat alternatives (Bryant & Sanctorum, 2021; Saint-Eve et al., 2021).
350 Italian consumers (almost 70% from 600 individuals) consider convenience of plant-based foods
351 as key factor to improve their diet (Contini et al., 2020).

352 In Germany, the plant-based meat products replace the muscle foods when the processed
353 plant meat foods resemble in texture and taste and are offered at affordable prices (Michel et al.,
354 2021; Saint-Eve et al., 2021). Females prefer consuming more plant-based foods because of the
355 animal welfare and environment concerns, while males consume the alternatives due to the taste
356 and price. For the insects, most people in the Western Countries prefer eating the processed food
357 compared to edible insects because food neophobia was a barrier for people in the Western
358 countries (Hartmann et al., 2015).

359 The meat consumption in Switzerland is categorized high (Hartmann & Siegrist, 2017). To
360 increase the meat alternatives consumption, ensuring a meat like experience can attract meat
361 lovers to consume alternative products having similar appearance and taste compared to meat
362 (de Boer et al., 2013)Information related to the environmental impact might not be effective,
363 since the awareness to the environmental issue is relatively low (Hartmann & Siegrist, 2017)

364 People in Denmark and Finland prefer the foods containing high protein content derived
365 from plants. Plant-based products are mainly considered healthier, more environmental friendly,
366 and as sustainable options than meat products (de Boer et al., 2013; Niva & Vainio, 2021). People
367 do not change to meat alternatives only due to the ethical issue (Hoek, 2010). Danish people
368 have also negative response to plant-based food products. Prices of food beverages in Denmark
369 are relatively higher than other European countries. Therefore, Danish consumers tend to prefer
370 locally produced foods when choosing plant-based products (Aschemann-Witzel & Peschel,
371 2019a). However, the acceptance of the meat alternatives is possible, if consumers know more
372 about alternative products. The females have more preference to consume the meat alternatives
373 than do the males. The low interest of plant-based food sensory and taste, the higher rate in price
374 prevent people to change the behavior to consume meat alternatives (Bryant & Sanctorum, 2021;
375 Hoek, 2010). People with higher education have also more preferences because they have more
376 information about the benefits of the meat alternatives and the health concerns excessive
377 overconsumption of meat products (de Boer et al., 2013; Hoek, 2010; Schösler et al., 2012). In
378 Finland, consumers plan to increase the consumption of plant and insect-based products (26%
379 and 24%, respectively) in the future (Niva & Vainio, 2021). However, in UK, 90.6% are willing
380 to consume plant-based products, while very few of them are willing to consume insect food
381 products.

382 In USA, the market potential of the plant-based foods is growing very quickly and can be
383 estimated to around or more than 17% (van Loo et al., 2020). Vegetarian, male, young, and with
384 high education individuals have strongly to consume meat alternatives. For the Chinese
385 consumers, they mainly reject or decline to consume plant-based foods because they have a
386 strong insight on meat as a pleasure (hedonism) (Qi & Ploeger, 2021). They historically assume
387 that food containing higher protein and fat is a pleasure (Qi & Ploeger, 2021). It does not mean
388 that the Chinese do not want to consume plant-based foods. It is important to consider that most
389 Chinese dishes are indeed plant-based foods due to their habits and culinary culture mostly
390 involving several plants and vegetables (Wang & Scrimgeour, 2021b). For the insect foods,

391 Chinese have a higher willingness to eat them, either processed or edible insects since it is
392 already a part of their food repertoire and culture (Gmuer et al., 2016). Verneau et al., (2021)
393 conducting an Entomophagy Attitude Questionnaire (EAQ) towards intention to eat insects for
394 the Chinese regarded as eaters found more positive interest or attitude to consume the edible
395 insects, compared to non-insect eaters' intention influenced by the role of disgust.

396 In South America, although people in Chile are categorized as non-insect eaters, they have
397 intention to try insect foods, even to adopt the insect foods into their own' meat or foods (la
398 Barbera et al., 2021). However, the visibility of insects influence their willingness to try since
399 the consumers are more reluctant to direct entomophagy (la Barbera et al., 2021; Verneau et al.,
400 2021). On the other hand, in many African countries, insects' consumption is regarded as
401 traditional practice (Grabowski et al., 2020). For example in South Africa, most people consume
402 insects because of e a nutritious food and the important role of insects for people's livelihoods
403 in rural areas (Hlongwane et al., 2021). Acculturation and insect availability could decline
404 entomophagy and become a challenge for insects' consumption in Africa (Hlongwane et al.,
405 2021).

406 Meat consumption in New Zealand is relatively routine since meat is acknowledged as a
407 traditional diet. However, the influence of Western people is very strong, which might affect the
408 habits of meat consumption in the country (Wang & Scrimgeour, 2021b). In Australia, a study of
409 meat alternatives perception revealed that Australian consumers feel no benefits from eating the
410 plant-based foods. As a result, the Australian was not ready to change the eating behavior toward
411 the consumption of meat alternatives (Hoek et al., 2017).

412 **6. Consumers perceptions to insect-, seaweed- and plant-based products**

413 A transition to consider meat alternatives offers new interest on vegetables and grains
414 (Holm & Møhl, 2000). Several studies reported meat reducers (flexitarian and plantarian) and
415 meat avoiders (vegetarians and vegans) (Kanerva, 2013; Possidónio et al., 2021). For example,
416 37% of consumers in Finland consume beef, and there are no consumptions of insect- or plant-
417 based protein products (Niva & Vainio, 2021).

418 The strong relationship between healthy and sustainable food perceives a clear relationship
419 between attitudes and behaviors. Consumers reducing meat consumption have higher
420 perceptions of the environmental effects, health awareness, and lower disgust sensitivity, and
421 they are in general younger, females, and more educated (Bryant & Sanctorum, 2021; Graça et

422 al., 2015). Health awareness, gender, education, income, and age positively affect the trend of
423 plant-based foods consumption in European Countries. The better consumer understanding on
424 the environmental effect attract more consumption on sustainable food. These results agree with
425 the statements by (de Boer et al., 2013) who reported that consumers who value nature are also
426 more willing to switch to meat-free diets. Therefore, switching to a plant-based product is
427 regarded as a behavior giving more attention to healthy and sustainable consumption.

428 Meat alternatives are expected to have similar texture, taste, and ease of preparation to
429 muscle foods (Faber et al., 2020; Michel et al., 2021). In terms of social issue and regarding
430 different consumption situations, meat alternatives are considered more appropriate to be
431 consumed alone or with family or friends (Michel et al., 2021). However, consumer preferences
432 are not yet fully understood since they are dynamic and not stationary. In line to this, (Bekker et
433 al., 2017) reported that attitudes can be changed with marketing campaigns, or social norms can
434 influence the willing of consumers to eat plant- or insect-based products (Banovic & Otterbring,
435 2021). In addition, most consumers do not believe than plant based-burgers have similar taste to
436 that of conventional meat. It is important to produce a plant-, seaweed-, and insect-based burger
437 with a convincing taste as muscle beefs' tastes to obtain or secure a higher market share.

438 **7. The drivers to increase the acceptance of meat alternatives**

439 Consumers do not often realize environmental and health effects of muscle meat and do
440 not have a willingness to change their meat consumption habits (Hartmann et al., 2018;
441 Hartmann & Siegrist, 2017). With consideration of more sustainable foods' transitions, it is
442 important to have a better understanding of consumers' motivators/demotivators and establish
443 interventions to improve the consumer acceptance toward meat alternatives.

444 Combining sensory evaluation with instrumental results could be beneficial to optimize
445 the ingredients and/or to modify the sensory characteristics and to improve the final product,
446 hence increasing the consumer acceptance. Meat alternatives can successfully replace meat when
447 taste and texture are very similar to those of processed meat products at competitive prices (Graça
448 et al., 2015). Meat alternative producers are recommended to focus on replicating the processed
449 meat products instead of imitating the meat like escalope or steak. Under certain conditions, such
450 as plant-based burgers, even though consumers are conveyed that all burgers has the same taste,
451 the preferences for beef burgers are still noticed. As an example, women prefer to purchase the
452 plant-based burgers, but less possibility to purchase the cultured meat burgers (Bryant &

453 Sanctorem, 2021; Hoek, 2010). For the insect foods, another way can be performed by
454 incorporation of the insect foods into familiar ones, that can reduce negative attitudes and
455 neophobic reactions (Hartmann et al., 2015). In opposite of the plant-based products, males are
456 over 2 times more acceptable than females (Verbeke, 2015).

457 Communication such as targeted marketing campaigns and social media influencers play
458 an important role, so an efficient campaign related to the meat alternatives must be to the point
459 and well-delivered to the targeted consumers. The campaigns should focus on the most important
460 message that the costumers need to know about the meat alternatives products (Schiano et al.,
461 2020; Schouteten et al., 2016). Thus, it may be useful to reinforce the motive for selecting the
462 plant-based food products due to health concerns against muscle foods and meat (Hoek et al.,
463 2017; Schouteten et al., 2016). In addition, it may be important to highlight the sustainability
464 aspect of the product. Another way might give a concern towards meat substitute ingredients by
465 changing the product from animal-based ingredients. This perspective improves the lists of
466 ingredients by increasing transparency and focusing on the familiar and harmless ingredients
467 (Aschemann-Witzel & Peschel, 2019b; Onwezen et al., 2021). Therefore, the health aspect must
468 be considered when the plant-based foods are communicated as the main motive. The "healthy"
469 code scored highly on all measures of centrality. The trend of clean labels (Rondoni et al., 2020)
470 and high processing rates of plant-based products need to be underlined and are the main
471 challenges of plant-based foods (Dickson-Spillmann et al., 2011; Peschel et al., 2019). In terms
472 of managerial implications, rewarding a product by enhancing its health-concerning properties,
473 supported with an effective communication, would seem more potential in consolidating the
474 alternative market. As an example, producing products containing high-quality ingredients
475 and/or no additives (Brückner-Gühmann et al., 2019), instead of preserving the products by using
476 high-pressure treatments, may respond to the health concerns wanted by the market (Barba et
477 al., 2015). In addition to providing information, non-informational approaches where consumers
478 are encouraged to healthier and more sustainable behaviors are gaining interest (Profeta et al.,
479 2021b; Reisch et al., 2017).

480 **8. Future implementation and action to support insect-, seaweed-, and plant-based** 481 **products as alternatives to meat and meat products**

482 The motive to opt for hedonic food is preferred for the future when ideological drivers of
483 consumer are not strong and the willingness of consumers to change their behavior (Bryant &
484 Sanctorem, 2021) An example of the behavior might be reducing animal product consumption

485 and increasing meat alternatives, *e.g.* plant- and insect based products. Besides the cooking skills
486 and healthiness, the satisfaction and taste are regarded as main barriers to keep the consumption
487 of muscle foods (Hoek, 2010; Niva & Vainio, 2021; Schösler et al., 2012). This barrier does not
488 only affect the communication strategy, but also the policy implementation and other industry
489 actions. As an example, a new dietary guidelines is established by considering not only health
490 and environment, but also palatability aspects. Similarly, reformulation of food products should
491 be based on consumer acceptance while combining sustainability and health criteria (Dötsch-
492 Klerk et al., 2015).

493 Public sectors are required to give a training for the consumers to conduct an assessment
494 quality of information related to food product innovation (Vainio, 2019) Consumers consuming
495 meat-based products have a scepticism of scientific evidence, due to less willingness and ability
496 to evaluate and filter information. Many scientific evidence are focused on healthy diet pattern,
497 providing a framework for food policies and strategies to support consumers eating the healthy
498 food products (Hawkes et al., 2013). These strategies include interventions in school
499 environment, economic instruments (taxes and subsidies), and food labeling (Lazzarini et al.,
500 2017). The global and important policy proposed by the governments are food-based dietary
501 guidelines (Hawkes et al., 2013), offering recommendations for types, amounts and number of
502 food that should be consumed to keeping health and prosperity. These recommendations should
503 also be of great help to consumers to make the purchase decision. Even though the global dietary
504 guidelines is focused only on health aspects, a growing number of nutritionists and public health
505 experts suggest that the future dietary guidelines must include also environmental and nutritional
506 aspects (van Dooren et al., 2014). Nowadays, the USA Dietary Guidelines Advisory Committee
507 (February 2015) reports that the environmental impact should be included in the Dietary
508 Guidelines for Americans (USDA, 2015). In Sweden and The Netherlands, dietary guidelines
509 have been launched, in which the environmental aspects are included.

510 Knowledge related to the food products may not have a positive implication automatically
511 on consumer' food behaviour. However, it is proven that the nutritional knowledge is associated
512 with consumer behaviour on healthier food consumption (Hartmann & Siegrist, 2017; Michel et
513 al., 2021; Siegrist et al., 2007). The environmental effects of foods perceived by consumers affect
514 consumer food behaviour. The increasing knowledge of the general public about the
515 environmental impacts of a variety of food products can give positive effects on the sustainability
516 of the consumer choices. Consumer decisions are influenced by a wide variety of factors as
517 previously explained (Renner et al., 2012b). Consequently, it is difficult to improve the

518 sustainability as a driver of food choices, so steps of action are required. For example, the
519 provision of knowledge related to environmental consequences from the food choices can be
520 included among the information on product label. This action could not change each consumer
521 behaviour, but some consumers still have a willingness to change their behaviour to consume
522 meat alternatives.

523 **9. Conclusion and prospects**

524 The demand for meat and meat products will continue as population and per capita income
525 is increasing throughout the world. As such, the replacement of meat-by-meat substitutes could
526 be a valuable alternative to reduce meat production burden from ethical, environmental and
527 nutritional perspectives. However, the acceptance of meat alternatives is still controversial.
528 Therefore, it is important to understand the consumers' preference for the meat alternatives that
529 mimic meat better. This review provides insights to better understand the consumer perception
530 and acceptance of plant-, seaweed-, and insect-based foods. Consumer acceptance varies with
531 alternative food products *e.g.*, plant-based foods are more acceptable than insect-based foods.
532 Different factors such as healthiness, taste, familiarity, attitudes, social norms, food neophobia,
533 and digestion are related to consumer acceptance of alternative meat products.

534 To attract the consumers and/or non-vegetarian, functional ingredients need to be
535 incorporate into the alternative food products in such way that it generates meat-like sensory
536 attributes. Future studies need to understand what the important factors or sensory attributes that
537 are more related to consumer acceptance of the alternative meat products. Hedonic test (*e.g.*, 9-
538 point hedonic scale) is useful to evaluate the overall consumer acceptance and to determine the
539 individual sensory attributes such as aroma, texture, appearance, overall liking, etc. On the other
540 hand, descriptive analysis will help to determine both qualitative and quantitative results of the
541 products' sensory profiles. Likewise, instrumental analysis and high throughput omics methods
542 are necessary to determine the texture, color, and to identify the important aroma-active and
543 other macromolecules compounds. Then, combining sensory evaluation with instrumental
544 results could be beneficial to optimize the ingredients and/or to modify the sensory
545 characteristics and to improve the final product, hence increasing consumers' acceptance. Future
546 studies also need to focus on comparison with multiple factors (*e.g.*, comparison across
547 countries, consumer segmentation, alternative meat products) to understand what are the
548 attributes or factors are related to the consumer liking and/or acceptance of alternative meat
549 products.

550 **Conflict of Interest**

551 The authors declare no conflict of interest.

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